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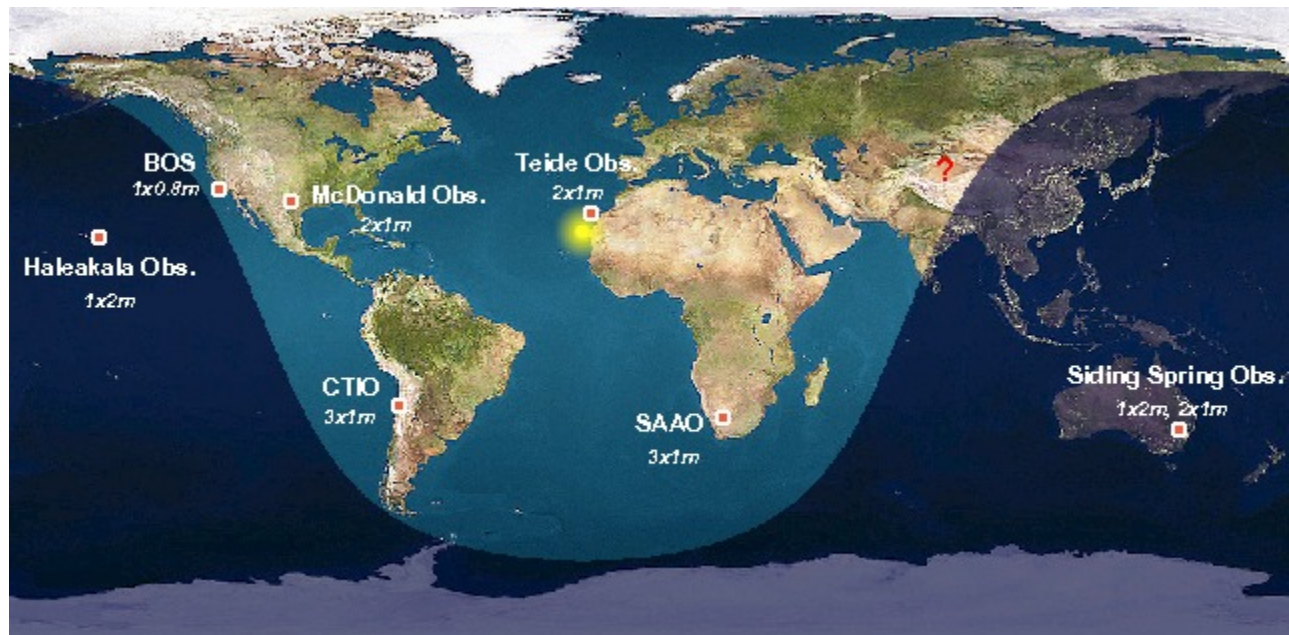
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Deployment Status of the Las Cumbres Observatory Global Telescope

A.J. Pickles, W. Rosing, J. Martinez, B.J. Fulton, D. Sand and LCOGT staff



Summary: Our global network of telescopes is designed to provide maximally available optical monitoring of time variable sources, from solar system to extra-galactic objects, and ranging in brightness from about 7-20m. We are providing a distributed network with varied apertures but homogeneous instrumentation: optical imaging, with spectroscopic capabilities. A key component is a single centralized process that accepts (in real time) and schedules TAC approved observing requests across the network; then continuously updates schedules based on status, weather and other availability criteria. Requests range from occasional to continuous monitoring, at slow to high-speed cadences (imaging and fast photometry), and includes rapid response to targets of opportunity. Each node of the network must be fully autonomous, with software agents to control and monitor all functions, to provide auto-recovery as necessary, and to announce their status and capabilities up the control structure. Real-time monitoring or interaction by humans should be infrequent. Equipment is designed to be reliable over long periods to minimize hands-on maintenance, by local or LCOGT staff. Our first 1m deployment was to McDonald Obs. in April 2012. Eight more 1m telescopes are close to deployment to complete the Southern ring, scheduled by end-2012.

Global Network: In the southern hemisphere, coverage is achieved by siting telescopes at three locations, roughly 8-hours apart: CTIO in Chile, SAAO at Sutherland, South Africa, and Siding Spring Observatory (SSO, ANU) in Australia.

Each site consists of 3 deep concrete piers surrounded by circular floors for 6-m diameter domes on custom (metal) wall sets. The walls were assembled at our workshops and shipped to site in pre-fabricated form, together with the domes shipped from Ash. They were assembled there by LCOGT and local staff from the host institution. Additionally each site has 3 rectangular

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pads for clamshell enclosures, again designed and built at our workshops and to be shipped to site^{1,2}. Each "Aqawan" clamshell can contain two 0.4m mounts, some supporting 0.4m telescopes, some supporting a range of ancillary instrumentation. <http://lcogt.net/network/0.4m>

Sites include conduits between each pad and a centralized "Site Services Building" (SSB), for power, network, data and spectroscopic fibers, and Clean Dry Air (CDA). The SSB is a SeaBox container assembled at Santa Barbara with site computers, UPS, safety equipment, and supporting a Site Environmental Monitoring System (SEMS). After assembly, each enclosure is equipped with control panels, connected to the SSB and network, and tested for remote operation, ready to receive pre-assembled telescopes. Sites and telescopes are made of modular components.



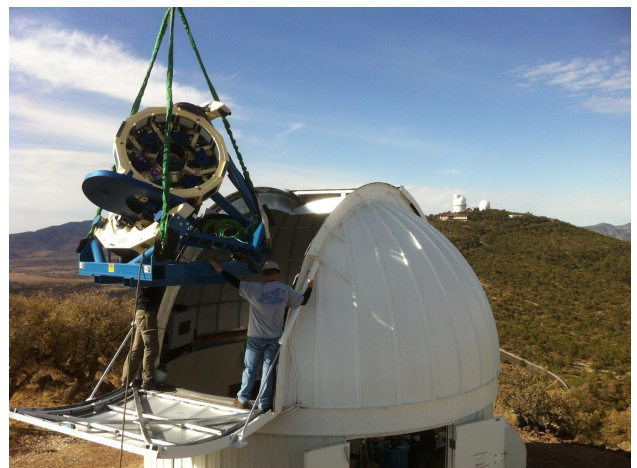
Fig 1. Three domes, SSB, Storage Container at CTIO.



Fig 2. Three domes at SAAO, and pads for Aqawan Clamshell

Figures 1-2 show details of the installed infrastructure at CTIO and SAAO, as of June 2012. Domes are complete and control panels and power and IT connections are being installed. Our goal is to have eight 1-m telescopes operating at these two Southern sites and SSO by end-2012, together with the existing 2-m FTS at SSO. <http://lcogt.net/network/2m>

The Northern hemisphere geographical distribution is more complicated. As a monitoring organization, we prefer established sites with clear weather, reasonable image quality, and host institutions that we can partner with technically and scientifically. These include Haleakala on Maui (2-m FTS, U. Hawai'i), Byrne Observatory at Sedgwick (BOS 0.8m, UCSB), McDonald Observatory (U. Texas), Teide Observatory (IAC) in the Canary Islands, and a potential site in China. Fig 3. shows the currently working 1-m telescope being installed at McDonald Observatory. <http://lcogt.net/network/1m>



Existing and ongoing deployments are summarized in the table. Numbers in parentheses are constructed but still to be deployed. We have two working 1m telescopes, at McDonald and Santa Barbara (SBA), and eight being assembled in our shops; we have parts for 6 additional 1m telescopes. We have two working 0.4m mounts at SBA, and more being assembled. One cross-beam 0m4 mount is being used at FTN, Haleakala for the [ASAS-3N](#) survey telescope¹⁶. Three 1m telescopes will be deployed to each of CTIO and SAAO, and two to SSO by end 2012. Further development in the Northern hemisphere, and of 0.4m telescopes, will proceed after the Southern Ring is well established, and dependent on funding.

Site	2m	Domes	1m	0m8	Aqawan	0m4	Ready
FTN	1						2005
SBA		1	1		1	2	2010
BOS		1		1			2009
McDonald		1(+1)	1(+1)		(2)	(4)	Apr 2012, (2013)
Teide		(2)	(2)		(2)	(4)	(2014)
CTIO		3	(3)		(3)	(6)	(Aug 2012)
SAAO		3	(3)		(3)	(6)	(Oct 2012)
SSO	1	(2)	(2)		(2)	(4)	2005, (2012)

Telescope Capabilities and Instrumentation, see also <http://lcogt.net/network>

2m: FTN (Haleakala) and FTS (SSO), each F/10 alt-az + Cassegrain rotator, built by TTL

- **Merope** imager: E2V 42-40 CCD on a side port (3 mirrors), good QE in UV and Yband
 - **2Kx2K**, 0.14 arcsec pixels, 5-arcmin Field of View (FoV)
- **Spectral** imager: Fairchild CCD-486 BI, straight through port (2 mirrors)
 - **4Kx4K**, 0.15 arcsec pixels, 10-arcmin FoV, high QE in B-Z
- Both above with Johnson/Cousins UBVRI, Sloan primed ugri, PanStarrs ZsYs filters
- **NEW**: Folded Low Order whYte-pupil Double-dispersed Spectrograph, [FLOYDS](#)
 - R~500 330-1000nm flux calibrated spectra of faint sources^{3,20}

1m: Equatorial C-ring mounts⁴, steel and carbon-fiber OTA⁵. Cass F/8 imager and 4 off-axis folded side ports for autoguiding, LIHSP⁶ and fiber-fed spectroscopy⁷.

- Currently SBIG 16803 4Kx4K CCD, 0.23 arcsec pixels, 16-arcmin FoV
- 2013: replace by **Sinistro CCD-486 BI** imager, Cryotiger cooling
 - same CCD as Spectral, but LCOGT electronics for fast & low-noise readout
 - 0.39 arcsec pixels, 27-arcmin FoV, flexible readout modes⁸
- Both with custom Astrodon UBVRI, ugri, ZsYs, nb filters and carbon-fiber shutter wheel
- **Andor iXon-3** EM-CCD, 1Kx1K, 0.3 arcsec pixels, 6-arcmin FoV, LIHSP
- Fiber Feed to Medium Resolution Spectrograph lcogt.net/network/instrumentation/nres

0m4: C-ring mount, Carbon fiber tube, Meade F/8 Optics

- LCOGT mount, drive, focus and Blackfin control
- SBIG STX-6303 CCD, 2Kx3K, 0.6 arcsec pixels, 20x30-arcmin FoV
- or Andor Luca-R EVM-CCD, 1Kx1K, 0.3 arcsec pixels, 5-arcmin FoV

Typical exposure times for an $r=18$ mag object in half-moon to $S/N=100$ for different apertures.

2m	1m	0m4
40sec	120sec	800sec

Network and Telescope Control Software

LCOGT have designed and built a comprehensive new java based Telescope Control System (jTCS) utilizing the Java Agent DEvelopment (JADE) framework⁹. This is working on our 1m and 0m4 telescopes, and will be retro-fitted to our 2m telescopes to bring them into the globally scheduled network. All functionality is available via web URLs to provide a variety of engineering and user interfaces. Briefly this framework provides:

- Astrometric agent and guiding based on the TPK kernel¹⁰, and using astrometry.net for automatic WCS fitting in real-time.
- Automatic [Tpoint](#) modeling using automatic WCS fits to images. Currently we are achieving better than 10-arcsec RMS pointing across the sky. These features are also used during deployment to calculate fixator adjustments for accurate polar alignment of equatorial mounts.
- Agents monitoring IERS bulletins, to configure each telescope, for each instrument and their relative positioning within the focal plane. Each instrument is automatically aligned on-sky.
- Agents to control and monitor multiple instrument and guider selection, filter wheels, exposure and subsystem control for scheduled observations. Guiding can be configured on any instrument, for self-guiding or off-axis instrument guiding.
- Agents monitor, and attempt to recover any subsystem, including power-cycling when necessary, to maintain autonomous operations.
- Transparency agent compares [sextractor](#) magnitudes of stars measured in each field (any filter), matched via fitted WCS coordinates to standards from Landolt, Stetson, Sloan (including Southern standards), Tycho and [APASS](#).
- Context camera(s) deployed at each site to monitor extinction and photometric quality.
- Flash reduced data available on-site for automatic quality checking.
- Proposal Observation Network Database (POND) monitors observations from request to completion.
- Observatory Reduction and Acquisition Control (ORAC-DR¹¹) pipeline to remove instrument signatures and derive source information stored in a DB hosted by IPAC.
- Network Scheduler to distribute and monitor observations across the network, monitor weather and availability feedback from nodes, and re-schedule as necessary.

Recent Science Results

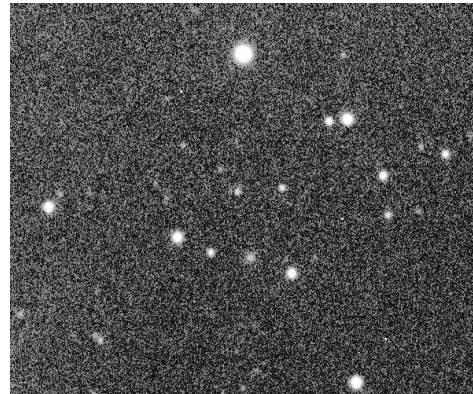
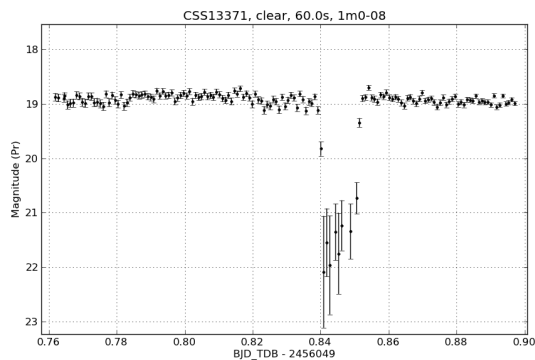


Fig 4. Light curve of a white dwarf (WD) being occulted by a cool faint object of unknown type, probably low mass star. Lowest points indicate the WD was not detected, as also seen in the video. From LCOGT 1m #08 at McDonald Obs, 2-May-2012 (BJ Fulton).

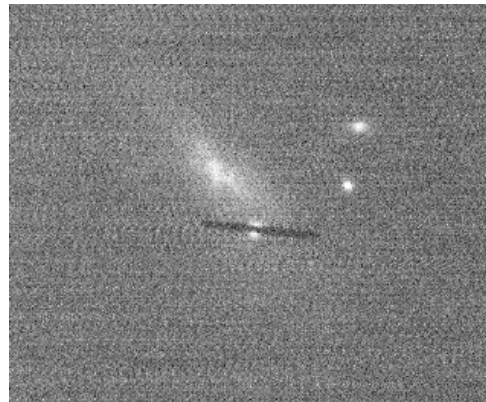
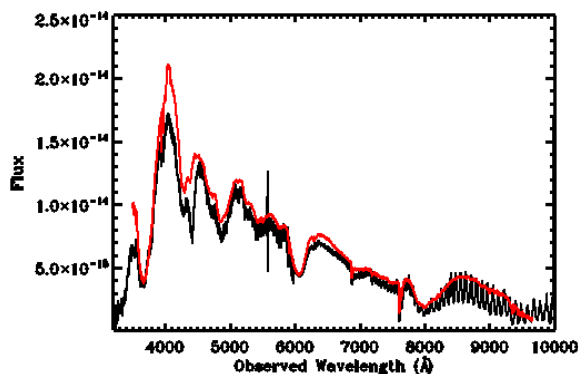
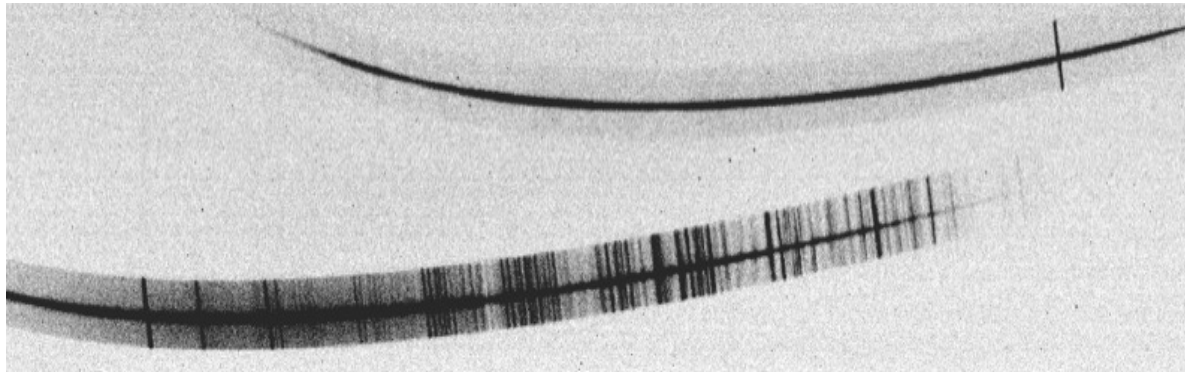


Fig 5. Spectrum of SN2012cg obtained recently with FLOYDS on the 2m FTS. Top: The two dimensional spectrum of SN2012cg as seen on the Andor Newton 2048x512 CCD: the first order spectrum extends from ~550 nm to 1 micron (lower trace) and the second order spectrum from ~320 nm to 570 nm (upper trace). Observing first and second orders simultaneously allows for efficient exposures and large wavelength coverage in a single exposure. Bottom Left: Extracted, flux-calibrated one dimensional spectrum of SN2012cg taken with FLOYDS in ten minutes of integration time (black), compared with Gemini/GMOS spectrum (red) taken within two days of the FLOYDS spectrum, with a three minute integration, suggesting that FLOYDS throughput compares favorably. Bottom Right: Acquisition image of SN2012cg, shown with the supernova in the slit.

In 2011 LCOGT astronomers contributed to over 100 refereed publications¹²⁻¹⁹, using [LCOGT](https://www.lco.org/)

and other facilities. Also in 2011 there were over 100 additional publications from other astronomers using LCOGT facilities, currently mainly FTN and FTS. We anticipate increased scientific output as our network grows, from our own scientific staff, partner organizations, and especially through the advent of key projects utilizing our facilities. LCOGT's goal is to deploy the network and use it scientifically and productively. All data will become public after a 12-month proprietary period, to facilitate science analysis of new and historical variable sources.

Partner science and [educational](#) organizations include the Faulkes Educational Trust, RoboNet, UH, UCSB, UT, IAC, CTIO, SAAO, ANU, and school groups in the UK and Hawai'i. The Scottish Universities Physics Alliance ([SUPA](#)), managed by St. Andrews University, has contributed to the deployment and operational costs of two Southern 1m telescopes, resulting in additional network time for them. LCOGT are exploring avenues for additional funding to complete and operate the Northern ring.

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